



Early Journal Content on JSTOR, Free to Anyone in the World

This article is one of nearly 500,000 scholarly works digitized and made freely available to everyone in the world by JSTOR.

Known as the Early Journal Content, this set of works include research articles, news, letters, and other writings published in more than 200 of the oldest leading academic journals. The works date from the mid-seventeenth to the early twentieth centuries.

We encourage people to read and share the Early Journal Content openly and to tell others that this resource exists. People may post this content online or redistribute in any way for non-commercial purposes.

Read more about Early Journal Content at <http://about.jstor.org/participate-jstor/individuals/early-journal-content>.

JSTOR is a digital library of academic journals, books, and primary source objects. JSTOR helps people discover, use, and build upon a wide range of content through a powerful research and teaching platform, and preserves this content for future generations. JSTOR is part of ITHAKA, a not-for-profit organization that also includes Ithaka S+R and Portico. For more information about JSTOR, please contact support@jstor.org.

EXPERIMENTS WITH MYCENAEAN GLAZE

IN a previous article in this JOURNAL¹ I asserted the belief that the black glaze employed in the black-figured and red-figured Attic styles of vase-painting is composed of a white clay colored by ferrous iron and rendered fusible by the admixture of some alkali. This belief arose from observing that, barring an excess of alkali in the glaze, the elements composing the clay of the vases are the same as those entering into the makeup of the glaze. The iron present predominated as ferric (red) oxide in the clay and as ferrous (black) oxide in the glaze.

If now in the black-figured and red-figured styles the glaze in its component parts proved to be the same as the clay with the exception that black oxide of iron predominated in the glaze and the red oxide in the clay, then in the Mycenaean style employing the red glaze analyses should show the red oxide to be present in larger amounts in the glaze than in the clay, for in this ware the glaze is distinctly redder than the clay. In other words, if the Greeks employed compounds of iron in the ferrous condition in combination with white clay to produce the black glaze, it is reasonable to assume that they used compounds of the same element in the ferric state to obtain the red glaze of the Mycenaean style.

But it will be remembered, from my previous article, that the employment of white clay was necessitated, in the production of the black glaze, by the fact that in ordinary clay the presence of the red oxide neutralized the effect of the black, so that the results were always unsatisfactory. In the case of the red glaze, however, the presence of the red oxide of iron in the clay should be just what is desired, for it would apparently obviate the artificial introduction of the red. Yet before

¹ Vol. XII, 1908, No. 4, pp. 417 ff.

it was possible legitimately to proceed to attempt the reproduction of the red glaze by reversing, as it were, the process employed in connection with the black, it was obligatory to discover by analysis if it were true that the Mycenaean glaze showed an excess of red oxide over the clay.

To determine this the following experiments¹ were performed by my colleague Professor William Foster of the Department of Chemistry in Princeton University.

A glaze-coated fragment of Mycenaean ware was placed in a platinum crucible, covered with a mixture of hydrofluoric and sulphuric acids and, with the exercise of great care to exclude all air so as to prevent the oxidation of the ferrous iron, heated until all the glaze was removed from the body of the clay. The amount of ferrous iron in solution was determined by means of standard potassium permanganate, and the amount, calculated as FeO, was found to be 0.44 %. Analysis of an equal weight of the body of the vase, without the glaze, showed 0.56 % of FeO present in the clay. The analysis of a fragment from a second vase showed 0.35 % and 0.43 % of FeO present in the glaze and the body respectively; while in a fragment from still another vase 0.17 % and 0.25 % of FeO were found.

These experiments, therefore, indicate that the body of the Mycenaean ware contains more ferrous iron than the glaze. This, it will be remembered, is the reverse of what was found to be the case in reference to the black glaze.²

The next step was to determine the total iron, as ferric oxide (Fe_2O_3) in the red glaze and in the body of the clay.

To do this as much red glaze as possible was scratched from a fragment of Mycenaean ware by means of a diamond point, and 0.5 g. of the fine powder was dissolved in a platinum crucible, as previously, by means of a mixture of sulphuric and hydrofluoric acids. All the iron thus being in solution, the ferric iron was next reduced to the ferrous condition with the zinc-platinum couple, and the total iron then titrated by means

¹ These are the first experiments, so far as I know, that have been performed upon Mycenaean clays and glazes. Some of the specimens employed I picked up at Mycenae, the others I selected in Athens from the results of the excavations at the Heraeum.

² Cf. Tonks, *A. J. A.*, 1908, p. 423.

of standard potassium permanganate solution. The total iron present as Fe_2O_3 (ferric, or red, oxide) was thus found to be 8.16 %. This gave the ferric iron present in the glaze. To determine the amount of this material in the body of the clay a similar sample of the body of the vase was treated in a like manner as the glaze, with the result that 7.36 % total iron (as ferric iron) was found to be present. After making allowances for the small amount of ferrous iron present in the clay (see above) *the glaze was found to contain considerably more ferric iron than the body of the vase.* A second experiment conducted upon a fragment of another vase confirmed this most conclusively.

This being settled, it now seemed possible to reproduce the Mycenaean red glaze in much the same fashion that the black glaze of the Attic styles had been reproduced; and since Foster's results were more or less the converse of those obtained from analyzing the black glaze, it was natural to attempt to reverse the processes which had been followed in making the black glaze. Where, therefore, ferrous, or black, oxide had been previously used I now undertook to substitute ferric, or red, oxide. In other respects the earlier experiments were followed. In those it had been found that pipe clay could be fused by adding nitrate of soda. So now pipe clay and soda were fritted together and mixed with red oxide of iron. So far as concerned the glazing, I experienced as much success as when reproducing the black glaze; but in every instance the glaze which entered the furnace a good red came out a black of more or less intensity according to the amount of ferric oxide introduced. It required about a score of trials to convince me that this change was not due to some accident; for in some instances air was allowed to enter the muffle, while in others it was carefully excluded. But either way the glaze was always black. Indeed, no other result could be expected, for ferric oxide, when heated, turns from red to black. This was known to Foster with whom I was working; but he had thought that possibly the oxide might act differently when placed in contact with the ingredients in the glaze and in the clay. These trials, however, showed that this view was erroneous.

The answer then to these experiments would seem to be that ferric oxide could not be the coloring substance. But this view assumes, as I did, that the red oxide of iron went into the glaze in the identical form in which the experiments showed it to be present. This of course need not be the case. The iron, in fact, might be in the glaze in an hydrated form, which, when heated, changes to that in which the analyses found it. This is what occurs in the process of baking the ordinary red brick; before entering the kiln the clay is, or at least may be, yellow in color, but when fired it changes from yellow to red as the water is driven off.

If such clay as is used in making these bricks turns red in baking, there could be no reason, so far as could be seen, why it should not do the same when producing a glaze. If, moreover, the red-burning clay could be so employed it would obviate the need of introducing coloring matter artificially and would as a result simplify the process and tend to support the postulate I had laid down in reference to the black glaze on Greek vases, namely, that the glaze is nothing but a clay made fusible by the addition of some alkali and colored by the proper material.

To discover therefore if a red-burning clay could be used in reproducing Mycenaean glaze, I obtained from Trenton, N.J., some yellow clay which turns red upon baking. This was mixed with nitrate of soda, applied to the surface of a piece of clay, and when it came out from the furnace it was red in color. The tone, however, was too dark. It required in fact some fifty trials to find that this Trenton clay when mixed in the proportions of three to one with pipe clay and then fritted together with nitrate of soda in the proportions of one part of the mixture to eight parts of soda gave the same red tone as was to be seen on a specimen of Mycenaean ware in my possession. It was also found that it was necessary to apply the glaze very thinly to obtain the desired results. An electric thermocouple showed that the temperature in the muffle furnace in which the baking was done was 980-990° centigrade.

Finally, to convince myself that the Mycenaean clay itself was capable of being fused into a glaze, I mixed one half a gram of Mycenaean clay, which had been reduced to a powder, with two grams of nitrate of soda and subjected it to the heat of the

furnace. The result was a coarsely fused, somewhat darkish, red glaze which, although imperfect, was good enough to lead one to believe that the fresh clay, which had never been baked, when properly combined with nitrate of soda or some other alkali, would produce the glaze of the ancients.

In reference to the reproduction of the glaze with other clays than the Mycenaean it goes without saying that the proportions of clay and alkali would necessarily vary according to the kind of clay employed. The proportions given in this paper therefore are not constant.

The following is, so far as I know, the first analysis that has been made of Mycenaean clays. The work was done by Foster.

Silica (SiO_2)	40.60%
Aluminium Oxide (Al_2O_3)	17.07
Ferric Oxide (Fe_2O_3)	6.93
Ferrous Oxide (FeO)	0.56
Calcium Oxide (CaO)	19.80
Magnesium Oxide (MgO)	4.42
Potassium Oxide (K_2O)	2.96
Sodium Oxide (Na_2O)	0.21
Carbon Dioxide (CO_2)	5.40
Water (H_2O)	2.95
Total	100.90

A partial analysis of another specimen by the same chemist gave the following results:

Silica	47.51%
Aluminium Oxide	20.40
Total (Fe_2O_3) Iron	8.89
Calcium Oxide	13.82
Magnesium Oxide	4.41
Loss by Ignition (H_2O and CO_2)	2.78
Total	97.81

OLIVER S. TONKS.

PRINCETON UNIVERSITY.